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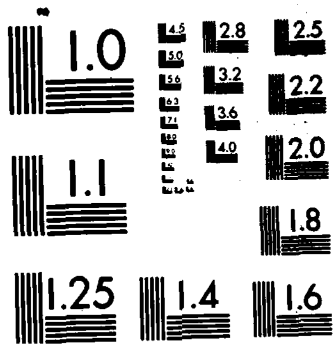

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APPLIED MARINE RESEARCH LABORATORY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

MACROBENTHIC COMMUNITIES OF THE NORFOLK DISPOSAL SITE - I.

By

Daniel M. Dauer, Principal Investigator
Department of Biological Sciences
Old Dominion University

Final Report
For the period ended May 30, 1984

Prepared for the
Department of the Army
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front St.
Norfolk, Virginia 23510

Under
Contract DACW65-81-C-0051
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The macrobenthic infaunal community of the Norfolk Disposal Site can be charaterized as a highly diverse community typical of undisturbed areas on the inner continental shelf of the Mid-Atlantic Bight which does not support any significant populations of commercially important macroinvertebrates. Analysis of seasonal and year to year trends in various community and species parameters indicates the need for continual updating of the baseline data set to avoid erroneous conclusions from future monitoring studies.

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MACROBENTHIC COMMUNITIES OF THE NORFOLK DISPOSAL SITE-I

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ABSTRACT

The distribution, abundance, and species composition of subtidal macrobenthic invertebrates of the Norfolk Disposal Site were studied. The macrobenthic infauna and the epibenthic fauna was sampled five times per year from 1979 through 1981 and four times per year in 1982 and 1983. The purpose of this study was: (1) to present recent information concerning the structure of marcobenthic communities of the Norfolk Disposal Site, (2) to compare the data generated by this study with data from previous studies of the inner continental shelf of the mid-Atlantic and the Southeastern U.S., (3) to develop multivariate statistical models based upon the baseline data and test the sensitivity of these models to simulated impacted data sets, and (4) to examine trends and variability in the data in order to assess future monitoring strategies.

The macrobenthic infaunal community of the Norfolk Disposal Site can be characterized as a highly diverse community typical of undisturbed areas on the inner continental shelf of the Mid-Atlantic Bight which does not support any signifcant populations of commercially important macroinvertebrates.

Analysis of seasonal and year to year trends in various community and species parameters indicates the need for continual updating of the baseline data set in order to avoid erroneous conclusions from future monitoring studies. Decreasing the frequency of sampling within each year could obscure any impacts upon temporally restricted phenomena such periods of peak juvenile recruitment.

INTRODUCTION

The distribution and abundance of the macrobenthic invertebrates of the inner continental shelf off the mouth of the Chesapeake Bay were studied. Density dominants, community abundance, species diversity, and animal-sediment relationships were determined for data from five stations off the mouth of the Chesapeake Bay. These stations were part of an environmental study of the area (designated as the Norfolk Disposal Site) proposed for open ocean disposal of dredged materials from the lower Chesapeake Bay (Alden et al. 1980, 1981a, 1981b). Samples were collected five times per year from February 1979 through October 1981 and four times per year from January 1982 through December 1983. Temporal patterns of the various community parameters and the abundance of the density dominants were emphasized. Multivariate statistical models were developed and tested.

The purpose of this study was: (1) to present recent information concerning the structure of marcobenthic communities of the Norfolk Disposal Site, (2) to compare the data generated by this study with data from previous studies of the inner continental shelf of the mid-Atlantic and the Southeastern U.S. (Boesch 1972, 1979a; Day et al. 1971; Frankenberg and Leiper 1977; Maurer et al. 1979a), (3) to develop multivariate statistical models based upon the baseline data and test the sensitivity of these models to simulated impacted data sets, and (4) to examine trends and

variability in the data in order to assess future monitoring strategies.

Materials and Methods

Field Collection

The macrofauna of the Norfolk Disposal Site was sampled at five stations located on two intersecting transects (Fig. 1). The Center Site was located at 36^{o} 59' N 75^{o} 39' W and the other stations were five nautical miles due north, south, east and west of the Center Site. Samples were collected five times per year from 1979 through 1981 and four times per year in 1982 and 1983.

During the initial cruise in February 1979, a rectangular box core sampler was used to collect benthic samples. The size of the collection box was 10x25x30 cm. Fifteen box core samples were collected from the Center Site (Fig. 1) in order to determine the sample size required for an *a priori* determined level of precision. At each of the other four sites, an initial arbitrary sample of five box core samples was collected. The operation of the box sampler proved to be dangerous and time consuming. Therefore, during the May, 1979, cruise a Shipek grab was used. During the May cruise an additional 15 grabs were collected from the Center Site in order to determine the sample size required. Each grab was washed through a 0.5 mm mesh-sized screen, relaxed with dilute isopropyl alcohol, and preserved and stained with

a formalin-rose bengal solution.

The data from the May cruise at the Center Site were analyzed to determine the number of Shipek grabs necessary to acquire a statistically reliable estimate of the density of individuals. Calculations were based upon the following formula:

$$N = \left(\frac{ts}{D\bar{x}}\right)^2$$

where: s = standard deviation of the prelimianry sample,

t = the tabulated t value at the 0.05 level with the degrees of freedom of the preliminary set of samples

x = mean density of the preliminary sample

D=required level of precision expressed as a decimal (Southward, 1966)

Previous work with benthic organisms has shown that an error of 30 to 35 percent of the mean will give a statistically reliable estimate (Dauer et al. 1979). With a 30 percent level of precision, 3.7 Shipeks per site would be necessary. Based upon this calculation and considering the manpower available, five Shipeks per site were used in the following cruises to characterize the benthic infaunal community.

At each station a small portion of the sediment (8 drams) was retained for sediment analysis. If the sediment from an individual grab changed markedly, an additional sediment sample was taken. The sediment was dry sieved using the techniques of Folk (1974). The mean particle size and

the sorting coefficient were determined graphically using the formulae of Folk (1974).

The epibenthic community was described from 10 minute trawl samples taken at the North, South and Center Sites during each cruise (Fig. 1). A 10-ft (3.05 m) beam trawl was used through May 1980, and a 10-ft (3.05 m) otter trawl for the remaining cruises. On the cruises in 1980 and 1981 samples were taken with a rocking chair dredge in order to be certain that no deeper dwelling commercially important species, e.g. the surf clam *Spisula solidissima*, were overlooked in our samples.

Community Analysis - Dominant Species

All infaunal taxa collected were used in the computation of indices of community structure. Shannon's informational diversity index, Margalef's species richness index, and Pielou's eveness index were calculated (see Ewing and Dauer 1982, for further details).

Detailed analysis of spatial and temporal patterns was conducted on selected dominant species. Taxonomically problematic taxa that could not be accurately identified to the species level were excluded (e.g. Oligochaeta spp. and Cirratulidae spp). Because some species were collected in very high numbers in only a few sites and/or collection times, dominance of species for the entire study was based upon the Biological Index Ranking (McCloskey 1970). For each cruise (a total of 22 cruises during the study) at each of the five sites the top ten density dominants were scored.

The species with the highest density recieved a score of 10, the species with the second highest density recieved a score of 9, etc. Rank density scores were summed over all cruises for the five years. Only the top 15 species were used in the following analyses.

The selected species were used in a normal classification analysis of the stations using the Bray-Curtis similarity coefficient and group average sorting on logarithmically transfomed data (Boesch 1977). For this analysis the mean density for each species for each cruise was used in the calculations.

Multivariate Models

Statistical models were developed to detect any future adverse environmental changes associated with disposal operations. The "sensitivity" of these models to a variety of potential impacts was tested using simulated impacted data sets (SIDS). For further discussion of the rationale of this approach see Alden et al. (1982).

The (SIDS) were produced by a computer program developed by Dr. R.W. Alden III. For each species used in the analysis the SIDS were generated to have the same frequency distribution as the baseline data, but with different mean values that represented potential impacts. Briefly, the program used a power law transformation to produce the best fit to the baseline data, changed the true mean to a desired mean, and then untransformed the data. Any desired number of replicates could be produced. SIDS were

produced with the same auto- and crosscorrelation relationships as the baseline data. In this study the chosen output was 25 simulated replicates for the top 15 density dominants. This simulated a single cruise (5 stations X 5 replicates per station) to the Norfolk Disposal Site. Five cruises from the 22 cruises taken to the site during the five year study period were randomly chosen for simulation. For each of these five cruises 10 different SIDS were produced as follows: each species reduced in mean density by 50%, 60%, 70%, 80% and 90%; each species increased in mean density by 50%, 100%, 150%, 200% and 250%. If none of these ten types of impacts were statistically significant as indicated by sensitivity testing (see below), SIDS beyond these ranges were produced until significant results were found. For each type of impact five impacted data sets were produced yielding 25 SIDS for each type of impact simulated.

Stepwise discriminant analysis was used to develop models to test for differences between groups defined _a priori_. Two groups were defined - one group was one of the randomly selected baseline cruises while the second group was one of the SIDS. Discriminant analysis produces a multivariate linear additive model that best descriminates between the defined groups. The model is then tested by classifying all replicates (baseline and SIDS) into one of the two groups, and checking the percentage of correct classifications. The optimal model will classify all replicates from the baseline data into one group and all replicates of the SIDS into the other group (100% correct

classification). For sensitivity testing a significant impact was declared to have occurred if greater than 95% of the SIDS replicates were correctly classified.

A second type of model was based upon the approach suggested by Green (1979) for baseline monitoring studies. A principal components analysis was conducted upon each of the five randomly selected baseline cruises. A principal components analysis produces a multivariate linear additive model with the first principal component accounting for the greatest amount of variance in the data set. The next principal component is independent of the previous one and accounts for the greatest amount of residual variance This process is continued for all remaining principal components. Green's approach produces a two-dimensional graph based upon the first two principal components. A 95% probability elipse is calculated for standardized principal component scores for the first two principal components. SIDS are next compared to the baseline data and the difference in principal components scores are plotted. If a plotted point lies outside the probabilty ellipse a significant impact is indicated; if within the probability ellipse no impact is indicated.

Results

Sediment Analysis

All stations had a very high sand content (Table 1). There appeared to be two potential groups of stations based upon sediment characteristics. The North and West sites were moderately well sorted sand with a mean particle size in the fine sand range (terminology of Folk 1974). The other three sites were moderately sorted sands with a mean particle size in the medium sand range. However, normal classification of the stations did not reveal any distinctive groupings (Alden et al., 1980, 1981a). Therefore all five sites were considered to be representative of a common macrobenthic community.

Community Analysis - Dominant Species

A total of 209 taxa were identified. Polychaetes comprised 51.2% (107 species) of the fauna, amphipods 14.8% (31 species), bivalves 10.5% (22 species), and gastropods 8.6% (18 species). See the Appendix for a complete listing of all species collected. In general the sites with the larger mean grain size (East, Center and South, Table 1) had the highest densities, highest species richness and lowest eveness values compared to the sites with the smaller mean grain size (North and West, Table 2). The higher community densities and lower eveness values of the East, Center and South Sites corresponded with high densities of the polychaetes *Spio setosa* and *Polygordius* sp. The higher

species richness values were affected by the collection of shells and by the presence of a dense interstitial component of the community. When shells were collected, species that attached their tubes onto the shell would be collected (e.g. Sabellaria vulgaris, Potamilla sp.) as well as species that foraged upon the shell colonists (e.g. Harmothoe extenuata). Coarse sediments contained species of interstitial burrowers, mainly annelids (Arabellidae: Arabella sp., Drilonereis longa, D. magna; Dorvilleidae: Protodorvillea kefersteini, Schistomeringos caeca, S. rudolphi; Lumbrineridae: Lumbrinerides acuta, Lumbrineris fragilis, L. tenuis; Opheliidae: Ophelia sp., Travisia sp.; Syllidae:Autolytus sp., Brania pusilla, Parapionosyllis longicirrata, Pionosyllis sp., Proceraea sp., Streptosyllis pettiboneae; Oligochaeta: Hemigrania postclitellochaeta, Tubificoides spp.). These interstitial burrowers were not unique to these sites but were simply more abundant; and therefore, consistently collected at the coarser sediment sites.

The top 15 density dominants of the Norfolk Disposal Site are shown in Table 3 and include 10 polychaete, 2 amphipod, 2 bivalve and 1 echinoderm species.

The temporal patterns of total community density and the species diversity indices are shown in Fig. 2. The temporal patterns of the top density dominants are shown in Figs. 3 - 5. For the total community parameters there were no repeatable seasonal patterns comparing the five years (Fig. 2). Total community density was highest in 1981, and was

primarily affected by high densities of *Polygordius* sp. in 1981 (Fig. 3B).

Several of the density dominants showed some form of seasonal pattern that was repeated between the years. The amphipods *Ampelisca verrilli* and *Protohaustorius deichmannae* generally showed a summer peak value each year that represented the time of juvenile recruitment (Figs. 3E and 5B). *Spio setosa* showed a peak density in winter or spring followed by a general decline for the summer. *Spio setosa* and *Magelona* sp. showed a general decline in yearly average densities (Fig. 4C,D), while *Amastigos caperatus* and *Mediomastus ambiseta* showed a general increase over the five years. The *Spisula solidissima* individuals were all juveniles - no individuals larger than 1 cm were ever collected. Apparently the population of *S. solidissima* at the Norfolk Disposal Site is never able to reach reproductive age.

The similarity dendrogram which clusters the sites organized by the five years shows a general pattern of greater similarity between sites within a year for 1979, 1982 and 1983, and a mixture of year and site groups for 1980 and 1981. Group A represents all sites from 1983, while B is the West Site from 1982. Group C is composed of all sites from 1982 except the West Site. Group D is composed of the North and South Sites of 1980 and 1981 with the West Site from 1981. Group E is composed of the East and Center Sites from 1980 and 1981 together with the West Site from 1980. Group F is composed of all sites from 1979 except for the North Site.

Group G is composed of the single North Site from 1979.

Table 4 summarizes the results of the trawl samples. Shown are the top ten density dominants for each site along with the frequency with which each taxon was collected. A total of 85 taxa were identified, but only 4 or 5 species were ever collected in 50% of more of the trawls. Two species, Crangon septemspinosa (the sand shrimp) and Echinarachnius parma (a sand dollar), accounted for 65.8% of all individuals collected in the trawl samples. No significant populations of commercially important species were collected in the trawls. No species were ever collected in the rocking chair dredges taken in 1980 and 1981.

Multivariate Models

Table 5 shows the results of the sensitivity analysis using the discrimiant models. For a given simulated impact the mean percentage correct classification is shown. These results indicate that with the existing baseline data a decrease in excess of 70% or an increase in excess of 100% would be required to produce a statistically significant change from baseline conditions.

The principal components model proved to be insensitive, and therefore, unacceptable for future impact assessment. For all randomly chosen cruises a total defaunation was never declared to be significant (i.e. was always plotted within the 95% probability ellipse). Increases in the range of 500-800% were necessary to indicate a significant impact.

DISCUSSION

Comparison with other studies

Dauer et al. (1984) previously reported the results from the first three years of sampling at the Norfolk Disposal Site. The additional two years of data did not change the top ten density dominants as reported in Dauer et al. (1984). The only major changes in the spatial and temporal distribution of the density dominants was the increase in density of *Polygordius* sp. at the fine sand North and West Sites, the generally lower overall densities in the last two years of *Spio setosa* and the general increase in density of *Amastigos caperatus* and *Mediomastus ambiseta*.

The macrobenthic infaunal community of the Norfolk Disposal Site can be characterized as a highly diverse community (see Fig. 6 in Dauer et al. 1984) typical of undisturbed areas on the inner continental shelf of the Mid-Atlantic Bight) which does not support any signifcant populations of commercially important macroinvertebrates.

Boesch (1979a) conducted a two-year survey of inner shelf communities off the coasts of New Jersey and the Delmarva Peninsula. He found that the total community density ranged between 2,000 and 10,000 individuals per m^2, which is comparable to our results (Table 2). Shannon's diversity values in Boesch's study for inner shelf stations had a median value of approximately 3.5 (estimated from a figure) compared with our 3.56. Eveness values of his study were estimated to average approximately 0.62, which is also

very comparable to our average eveness value of 0.68. Boesch's study compared benthic infaunal communities from the shallow inner shelf out to the continental slope. He characterized the inner shelf communities as being highly variable. However, his study was complicated by the hypoxic stress during the summer of 1976 that greatly affected the inner shelf communities.

Comparison of our data to Boesch's top 10 ranked density dominants of the inner shelf (Boesch 1979a, Table 6-6) reveals a moderate degree of similarity. All species listed by Boesch in the top 10 were collected in the present study except for his top ranked dominant, the tanaid _Tanaissus lilljeborgi_. Five of his other top ranked species were top ranked species in this study (_Spiophanes bombyx_, _Nephtys picta_, _Tellina agilis_, _Polygordius_ sp. and _Echinarachnius parma_). Two of Boesch's top ranked species _Goniadella gracilis_ and _Lumbrinerides acuta_, were collected at our sites only when sediments were coarse sands. The final species in Boesch's top 10, the amphipod _Pseudunciola obliquua_, was rarely collected in this study. The major difference between the density dominants of Boesch's study and the present study was probably due to the sampling of generally coarser sediments on the inner shelf by Boesch (see Boesch 1979b, Table 5-4).

Maurer et al. (1979) investigated the fauna of the inner shelf off the Delmarva Penisula. They provided a concise summary of "benthic invertebrates typical of sandy substrates" in the Middle Atlantic continental shelf region.

They proposed several species in each of the major invertebrate taxa as representative of the shelf region. In the polychaete category, Spiophanes bombyx, Nephtys picta, Polygordius sp., and Magelona sp. of our study were on their list. Five of the polychaete taxa they proposed were uncommon or not found in our study. Polychaete species in our study that were common density dominants and not listed by Maurer et al. were Amastigos caperatus, Apoprionospio pygmaea, Aricidea catherinae, Aricidea wassi, and Spio setosa. Of the five species of pelecypods listed by Maurer et al. as typical, only Cerastoderma pinnulatum and Spisula solidissima were in our study. Spisula solidissima and Tellina agilis were the only consistently collected pelecypods of our study. Of the seven amphipod species listed by Maurer et al., four were collected in our study (Protohaustorius deichmannae, Protohaustorius wigleyi, Trichophoxus epistomus and Unciola irrorata). Ampelicsa verrilli and Protohaustorius deichmannae were the only common amphipods in our study. Maurer et al. listed three species of isopod and three species of cumacean crustaceans as typical. None of these six species were collected in our study. Two decapod crustaceans were listed as typical by Maurer et al. (Cancer irroratus and Cancer borealis). C. irroratus was collected in our trawl samples (Table 4). Three echinoderm species were listed as typical. One, Echinarachnius parma, was collected in low densitites in our grab samples and occasionally in high densities in trawl

samples.

Day et al. (1971) conducted a transect study along the continental shelf off North Carolina. Their study did not have a very high similarity with ours. Of the eight annelids listed by Day et al. as dominants of comparable inner shelf sites, only four were ever collected in our study. Polygordius sp. and Magelona papillicornis (probably the same as our Magelona sp.) in the Day et al. study were also important species in our study. None of the dominant species in the other taxa (amphipoda, decapoda, pelecypoda, gastropoda) were even collected in our study.

Frankenberg and Leiper (1977) studied benthic communities off the Georgia continental shelf. They considered their fauna to be primarily subtropical in distribution. Their inner shelf sand community was dominated by Spiophanes bombyx, pelecypods of the genus Tellina, and by the cumacean Oxyurostylis smithi. They reported tremendous variation in the density of their top dominant, Spiophanes bombyx. Variations of three orders of magnitude in density at a single station and between stations separated by 5.5 km during the same month were recorded for S. bombyx.

The major density dominants in the present study have some similarity to studies in both higher and lower latitudes. However, differences do exist. Such differences may be due to major zoogeographic patterns of distribution with our study perhaps being a mixture of species dominant in the other studies. However, no distinct zoogeographic patterns seem to exist with the present data. Boesch (1979a)

studying over three degrees of latitide did not delineate any clear-cut biogeographic patterns. As Boesch has indicated, past geographic provinces were based primarily upon epifaunal echinoderms, decapod crustaceans, molluscs, and fishes. The dominant infaunal taxa, the polychaetes and peracaridean crustaceans, do not show distinct zoogeographic patterns. Cerame-Vivas and Gray (1966) proposed that the inner shelf of North Carolina off Beaufort was dominated by a Carolinean fauna while a Caribbean fauna dominated the outer shelf. The more infaunal oriented study of Day et al. (1971) did not support the pattern reported by Cerame-Vivas Gray.

Multivariate Models

The testing of the sensitivity of various multivariate models developed from the baseline data is useful (1) to indicate the magnitude of change necessary to produce a statistically significant difference and (2) to test if models may be relatively insensitive, and therefore, inappropriate for impact assessment.

The discriminant model showed that decreases in excess of 70% and increases in excess of 100% in the mean densities of the top 15 dominants (Table 5) would indicate a statistically significant difference from baseline conditions. An examination of the five year trend in density of the dominant species (Figs. 3-5) shows that this is a reasonable range of "warning values". For example, the species that showed the most repeatable seasonal pattern, *Ampelisca verrilli* (Fig. 3E), had 5 year mean density of 127

individuals per m^2 (Table 3). For A. verrilli the only time that its mean density exceeded a 100% increase in 127 (to 254) was during its peak summer increases when juvenile recruitment occurred (Fig. 3E). Also very rarely did mean densities over the five year study period fall below a 70% decrease from the five year mean density. A similar statement can be made for most of the top 15 density dominants. These results indicate that a discriminant model is a useful multivariate tool in impact assessment.

The graphical method of Green (1979), which is based upon a principal components model of the baseline data, was shown to be too insensitive to be useful in impact assessment. A principal components analysis produces models useful for indicating which potential factor(s) might explain or account for the greatest amount of variance in the data set. However, the two-dimensional graphical technique of Green does not declare a total defaunation as being significant; such a result is ecologically unacceptable. However, without the type of sensitivity testing used in this study this model may have been used in future impact assessment studies. In that case ecologically unacceptable alterations might occur which the model would say were not statistically significant. The necessity of sensitivity testing with simulated impacted data sets is obvious.

Monitoring Implications

The similarity dendrogram clearly shows that during most years of sampling, sites within a year are more similar to sites within the same year than to sites from previous years (Fig. 6). This implies that yearly events are to some degree unique events and extrapolation from previous years may be misleading or inappropriate. Comparisons become more risky the farther away in time the data are, e.g. comparing similarities between 1983 and 1979 data as compared to 1983 versus 1982 data. The need for continual updating of the data set and any models based upon the baseline data is obvious.

Identification and quantification of the temporal trends for the benthic community is necessary in order to avoid drawing erroneous conclusions from the data. The total community parameters such as the species diversity estimate (H', Fig. 2B) and eveness estimate (J', Fig. 2D) are fairly consistent parameters that should enable the detection of impacts in the macrobenthic community of a gross nature. However, more subtle but just as important impacts can occur through shifts in the dominant species. For example, a shift from a community dominated by surface deposit feeders to one dominated by subsurface deposit feeders could greatly decrease the value of the benthic community as a food resource for higher trophic levels such as commercially important fish. It therefore becomes important to also identify and quantify the natural temporal patterns of

distribution of the present dominant species at the Norfolk Disposal Site.

Summer density peaks of juveniles of the amphipod species *Ampelisca verrilli* and *Protohaustorius deichmannae* occur regularly throughout the five years of collection (Fig. 3E and Fig. 5B). Any deviation from this pattern offers a sensitive measure of potential impacts. In addition, surface dwelling amphipods such as these species are important items in the diet of bottom dwelling fishes. Juvenile stages are particularly vulnerable, and therefore, key constituents in the diet of fishes. Alterations in recruitment of juveniles, that could have profound effects upon fisheries, might not be reflected in the size of over-wintering populations of the amphipod species. The need for well defined within year variation on at least a seasonal basis is obvious.

Species with long term trends (more then one or two years) may be mistakenly interpretted as indicating that an impact has occurred, if such trends are not quantified. *Spio setosa* was a very common density dominant during most of the first three years of this study (Fig. 4D). During the final two years its density has greatly decreased (note that a logarithmic scale was used for the density) with no individuals collected on two of the cruises. *Amastigos caperatus* and *Mediomastus ambiseta* are two species whose densities have greatly increased during the final two years of collection (Fig. 5 A and D). The temporal patterns shown by *S. setosa*, *A. caperatus* and *M. ambiseta* indicate that

without regular sampling each year natural variation may be mistaken for an impact.

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Table 1. Summary of sedimentary parameters. Shown for each parameter are the means, standard errors (S.E.) and ranges calculated for all cruises from 1979 through 1983. A - mean phi, B - sorting coefficient, C -percent sand.

A. Mean phi

Site	North	South	East	West	Center
Mean	2.99	1.94	1.85	2.95	1.69
S.E.	0.04	0.17	0.27	0.21	0.19
Range	(2.47)-(3.38)	(0.09)-(3.08)	(-0.80)-(3.11)	(-0.08)-(3.42)	(-0.30)-(3.11)

B. Sorting coefficent

Site	North	South	East	West	Center
Mean	0.63	0.71	0.97	0.63	0.87
S.E.	0.02	0.03	0.07	0.04	0.04
Range	(0.41)-(0.78)	(0.43)-(1.00)	(0.62)-(1.75)	(0.48)-(1.37)	(0.63)-(1.36)

C. Percent sand

Site	North	South	East	West	Center
Mean	98.1	99.4	99.2	97.6	99.5
S.E.	0.17	0.23	0.20	0.30	0.15
Range	(97.1)-(99.2)	(97.3)-(100)	(97.4)-(99.9)	(95.6)-(99.9)	(97.6)-(99.9)

Table 2. Summary of total community parameters by site at the Norfolk Disposal Site. See Fig. 1 for site locations. Total community density in individuals per m2. H' - Shannon's informational diversity index, SR - Margalef's richness index, J' - Pielou's eveness index. Shown are means (one standard error).

Parameter	All Sites	North	South	East	West	Center
Total density	2,965 (666)	1,393 (218)	3,463 (708)	4,856 (829)	1,495 (278)	3,619 (518)
H'	3.56 (0.08)	3.69 (0.12)	3.55 (0.19)	3.27 (0.15)	3.60 (0.11)	3.67 (0.17)
SR	6.25 (0.36)	5.39 (0.18)	6.63 (0.24)	6.35 (0.28)	5.51 (0.21)	7.35 (0.39)
J'	0.68 (0.03)	0.76 (0.03)	0.66 (0.04)	0.60 (0.04)	0.73 (0.02)	0.66 (0.03)

Table 3. Density dominants of the Norfolk Disposal Site based upon density ranking analysis of data from all sites and cruises from 1979 through 1983. The spatial distribution among the sites is also shown as means (one standard error). See Fig 1 for site locations. Shown are individuals per m^2. Taxon code: A - amphipod, B - bivalve, E - echinoderm, P - polychaete.

Species	Total Rank Score	All Sites	North	South	Center	East	West
Polygordius sp. (P)	534.0	586 (123)	108 (25)	1,389 (557)	776 (212)	560 (114)	98 (22)
Spiophanes bombyx (P)	391.91	80 (14)	120 (13)	235 (37)	123 (20)	293 (51)	128 (13)
Nephtys picta (P)	345.4	66 (3)	67 (6)	112 (10)	63 (8)	40 (5)	48 (5)
Ampelsica verrilli (A)	326.6	127 (13)	327 (50)	58 (11)	30 (7)	78 (17)	143 (22)
Aricidia wassi (P)	304.0	71 (4)	88 (7)	93 (10)	75 (12)	93 (11)	4 (1)
Tellina agilis (B)	279.0	78 (6)	52 (7)	108 (17)	56 (10)	122 (19)	54 (6)
Apoprionospio pygmaea(P)	215.0	101 (12)	90 (34)	68 (17)	32 (10)	106 (20)	207 (37)
Spio setosa (P)	159.5	423 (110)	5 (2)	123 (68)	243 (118)	1,744 (517)	1 (0.5)
Aricidia catherinae (P)	147.8	57 (7)	51 (7)	64 (9)	39 (9)	131 (31)	1 (0.4)
Magelona sp. (P)	106.8	35 (4)	94 (15)	24 (4)	17 (3)	4 (1)	36 (5)
Amastigos caperatus (P)	101.5	62 (10)	12 (2)	111 (34)	10 (2)	8 (3)	172 (36)
Protohaustorius deichmanae (P)	99.0	30 (5)	31 (7)	32 (6)	85 (20)	1 (0.4)	0.2 (0.2)
Spisula solidissima (B)	73.0	32 (4)	17 (3)	46 (9)	67 (16)	20 (4)	14 (3)
Mediomastus ambiseta (P)	65.0	34 (4)	4 (1)	28 (7)	38 (9)	19 (3)	81 (16)
Echinarchnius parma (E)	57.0	36 (7)	48 (14)	55 (18)	42 (21)	9 (4)	28 (14)

Table 4. Summary of results of trawl samples collected from 1979 through 1983 by collection site. Shown for each site are the total number of individuals ot the ten most common taxa, their percent compostion of the entire number of individuals, and the number of trawls (frequency) that contained each taxon. A - North Site, B - South Site, C - Center Site.

A. North Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	3,004	43.8	20
Echinarchnius parma	2,084	30.0	16
Neomysis americana	438	6.3	3
Pagurus spp.	418	6.0	15
Nassarius trivittatus	391	5.6	18
Lolliguncula brevis	227	3.2	7
Asterias forbesii	82	1.1	10
Cancer irroratus	40	0.6	6
Crepidula fornicata	31	0.4	7
Crepidula plana	23	0.3	4
Total Individuals - 6,944	Total Species - 46		

B. South Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	3,482	47.7	19
Echinarachnius parma	1,685	23.1	17
Pagurus spp.	625	8.5	16
Nassarius trivittatus	534	7.3	14
Crepidula plana	172	2.4	4
Neomysis americana	160	2.1	3
Crepidula fornicata	107	1.5	5
Cancer irroratus	97	1.3	9
Lolliguncula brevis	88	1.2	4
Pleurobranchia tarda	76	1.0	7
Total Individuals - 7,299	Total Species - 54		

C. Center Site	Number collected	Percent of total	Frequency
Crangon septemspinosa	2,232	41.4	18
Neomysis americana	735	13.6	4
Pagurus spp.	657	12.2	15
Echinarachnius parma	397	7.4	14
Nassarius trivittatus	304	5.6	14
Cancer irroratus	172	3.2	14
Asrerias forbesii	169	3.1	11
Crepidula fornicata	117	2.2	8
Crepidula plana	66	1.2	6
Lolliguncula brevis	36	0.6	7
Total Individuals - 5,387	Total Species - 60		

Table 5. Summary of the sensitivity testing of the discriminant model based upon baseline data and simulated impacted data sets. First column indicates the type of impacted data set. Second column shows the average percent correct classification of the simulated impacted data sets. Each percent shown is the average of 25 replicates.

Simulated impact	% Correct Classification
50% decrease	93.8
60% decrease	92.5
70% decrease	95.8
80% decrease	95.7
90% decrease	96.5
50% increase	93.4
100% increase	99.4
150% increase	99.8
200% increase	100.0
250% increase	100.0

Figure 1. Study area. The Center Site (C) is located at 36° 59' N, 75° 39' W. The other 4 sites are located five nautical miles due north (N), south (S), east (E) and west (W) of the Center Site.

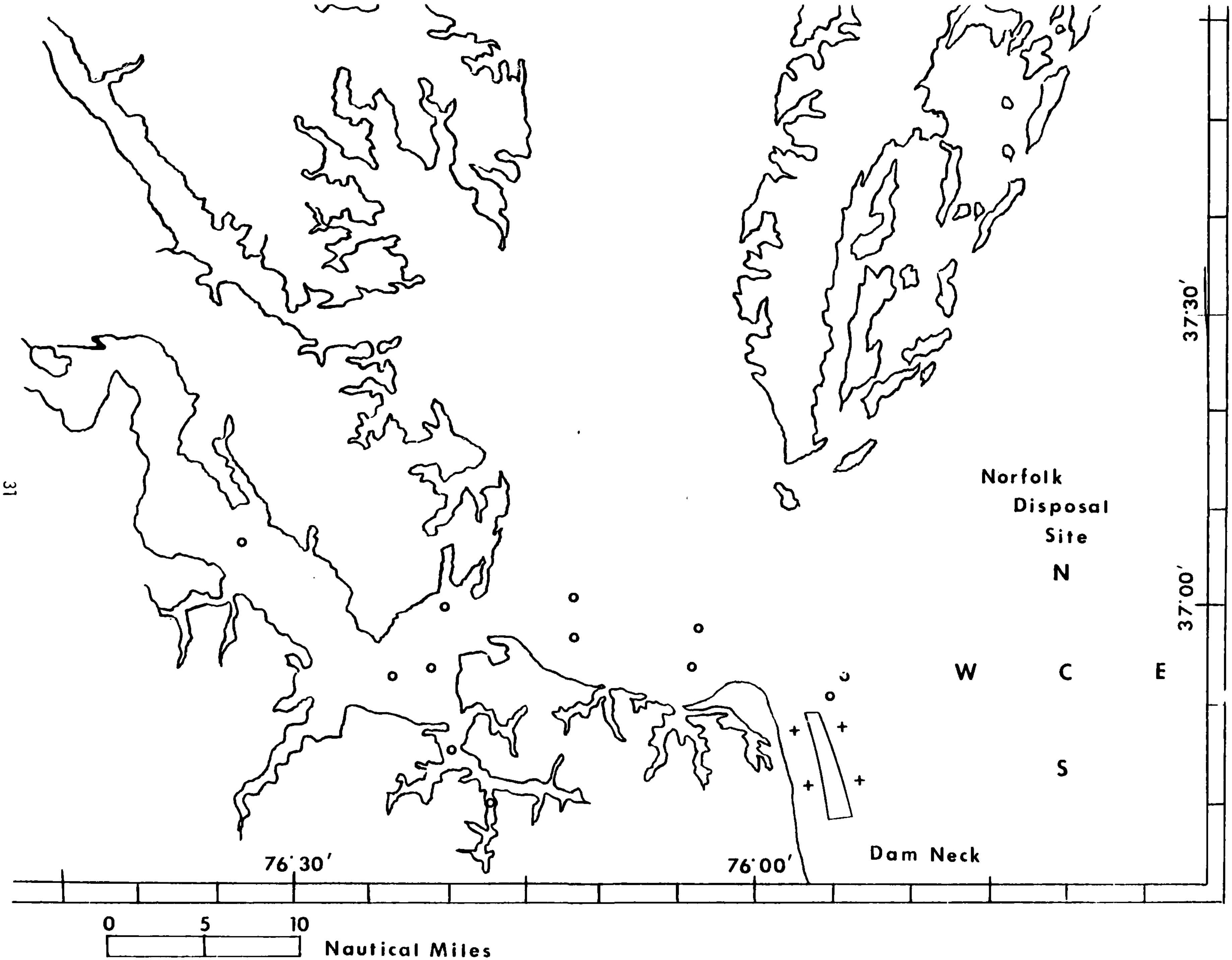

Norfolk
Disposal
Site
N
W
C
E
S
Dam Neck
37°30′
37°00′
76°30′
76°00′
0
5
10
Nautical Miles

Figure 2. Total community parameters for the Norfolk Disposal sites. Shown are means $\pm$ one standard error. A. Total community density (X 10^3 individuals per m^2). B. Shannon's informational species diversity index (H'). C. Margalef's species richness index (SR). D. Pielou's eveness index (J').

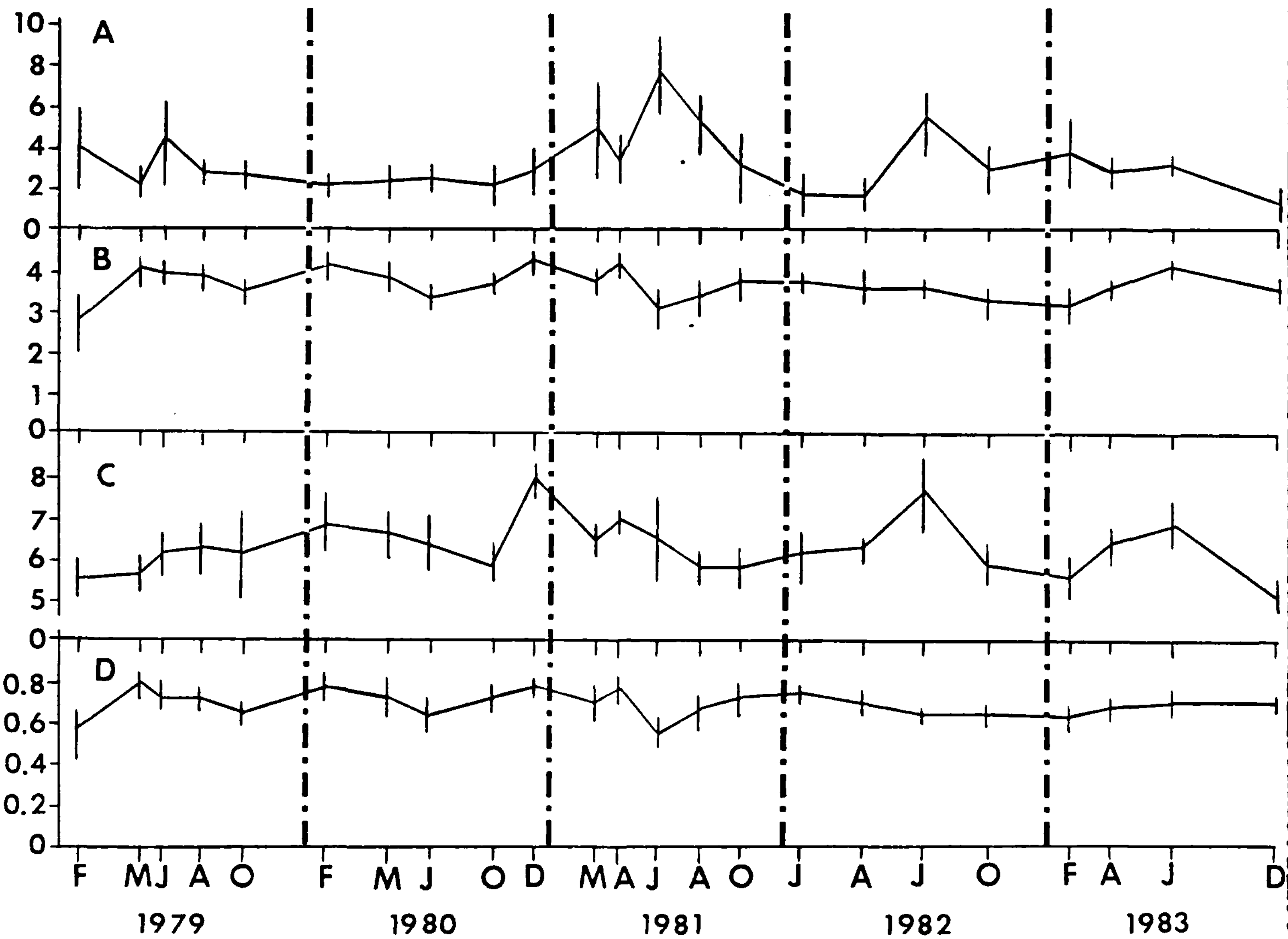
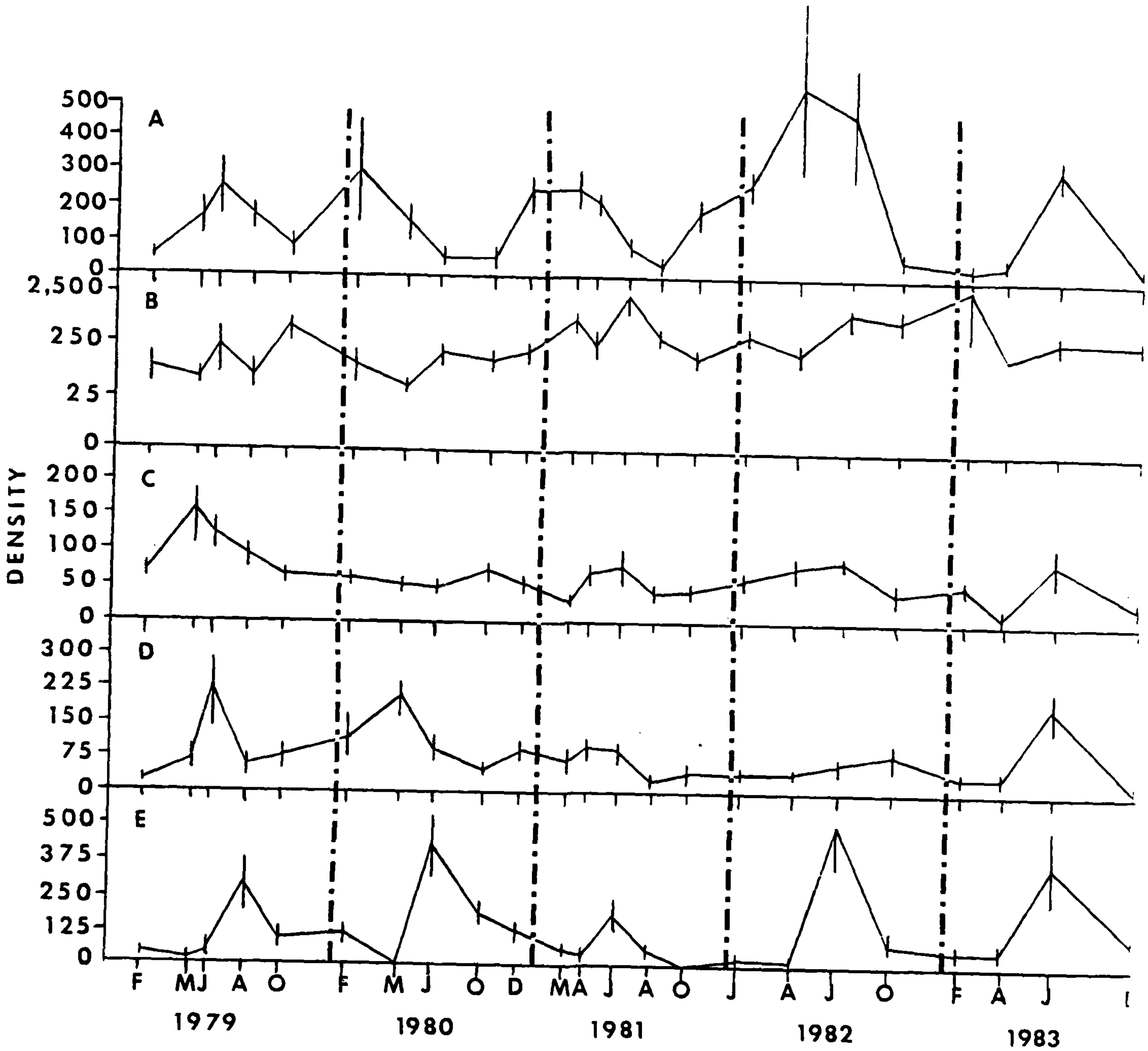
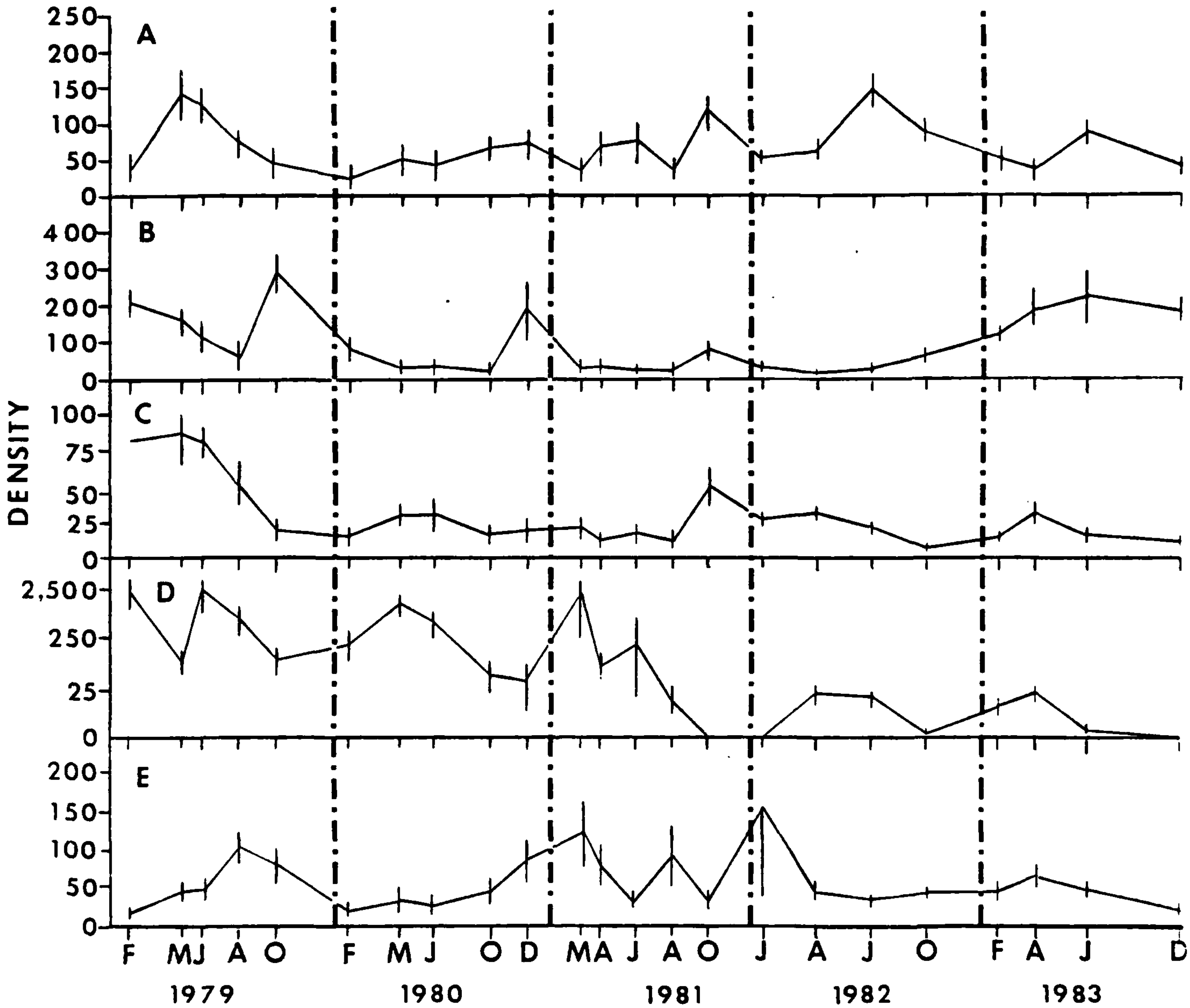

A
B
C
D
H′
10
8
6
4
2
0
4
3
2
1
0
8
7
6
5
0
0.8
0.6
0.4
0.2
0
F
M J
A
O
F
M
J
O
D
M A
J
A
O
J
A
J
O
F
A
J
D
1979
1980
1981
1982
1983

Figure 3. Temporal density patterns of dominant species at the Norfolk Disposal Site. Shown are means ± one standard error. A. *Spiophanes bombyx*, B. *Polygordius* sp. C. *Nephtys picta* D. *Tellina agilis*, E. *Ampelicsa verrilli*.



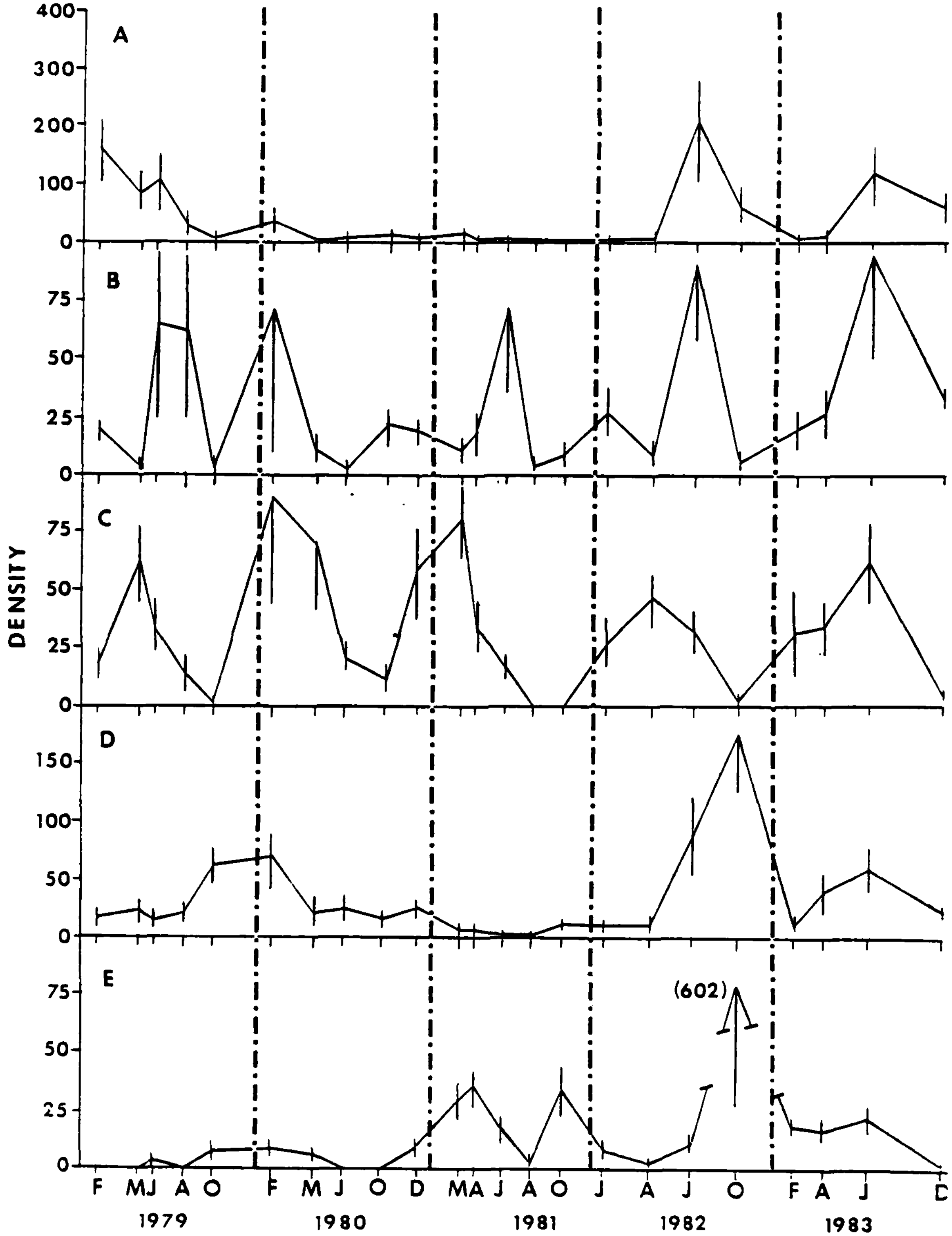
A
B
C
D
E
DENSITY
500
400
300
200
100
0
2,500
250
25
0
200
150
100
50
0
300
225
150
75
0
500
375
250
125
0
F MJ A O F M J O D MA J A O J A J O F A J
1979
1980
1981
1982
1983

Figure 4. Temporal density pattern of dominant species at the Norfolk Disposal Site. Shown are means ± one standard error. A. Aricidea wassi, B. Apoprionospio pygmaea, C. Magelona sp., D. Spio setosa, E. Aricidea catherinae.



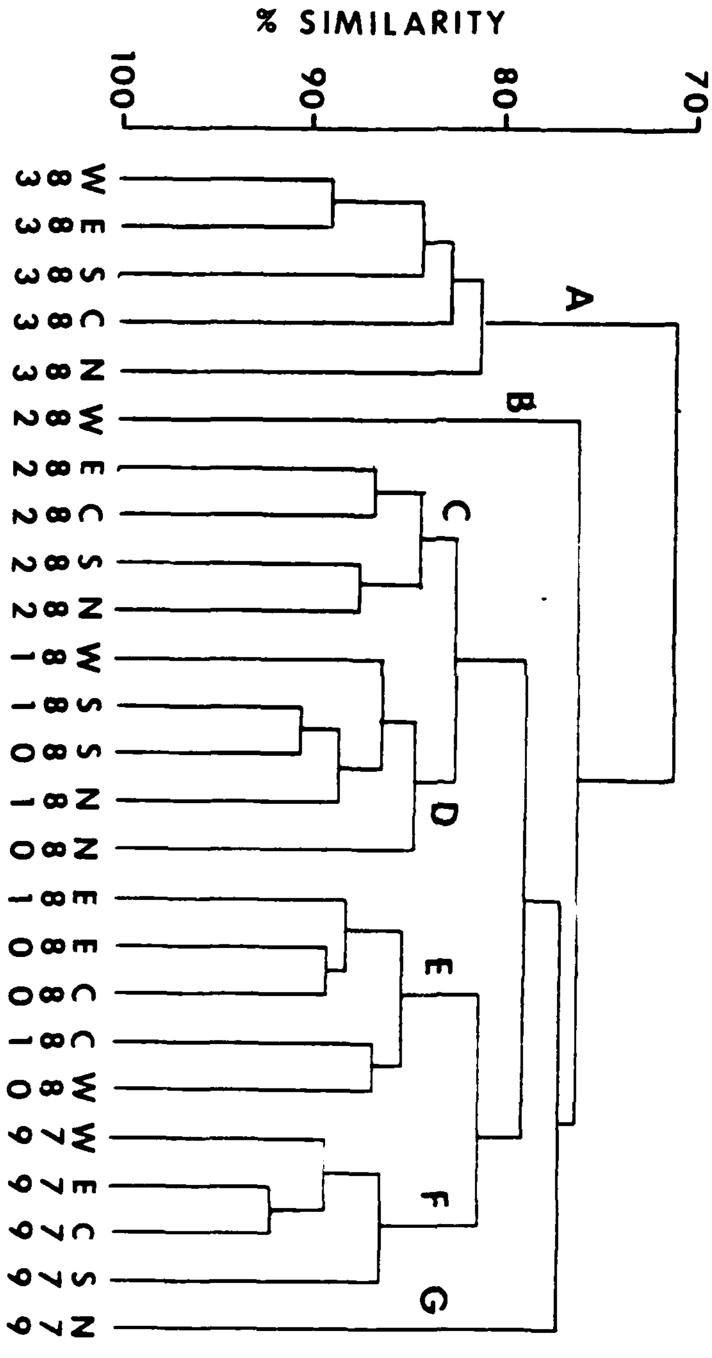
A
B
C
D
E
DENSITY
250
200
150
100
50
0
400
300
200
100
0
100
75
50
25
0
2,500
250
25
0
200
150
100
50
0
F MJ A O F M J O D MA J A O J A J O F A J D
1979
1980
1981
1982
1983

Figure 5. Temporal density pattern of dominant species at the Norfolk Disposal Site. Shown are means ± one standard error. A. *Amastigos caperatus*, B. *Protohaustorius deichmannae*, C. *Spisula solidissima*, D. *Mediomastus ambiseta*, E. *Echinarchnius parma*.



A
B
C
D
E
400
300
200
100
0
75
50
25
150
DENSITY
(602)
F
MJ
A
O
F
M
J
O
D
MA
J
A
O
J
A
J
O
F
A
J
D
1979
1980
1981
1982
1983

Figure 6. Similarity dendrogram of the five sampling sites for each of five years of sampling. N - North Site, S - South Site, E - East Site, W - West Site, C - Center Site.


% SIMILARITY
100
90
80
70
A
B
C
D
E
F
G
W 8 3
E 8 3
S 8 3
C 8 3
N 8 3
W 8 2
E 8 2
C 8 2
S 8 2
N 8 2
W 8 1
S 8 1
S 8 0
N 8 1
N 8 0
E 8 1
E 8 0
C 8 0
C 8 1
W 8 0
W 7 9
E 7 9
C 7 9
S 7 9
N 7 9

APPENDIX - SPECIES LIST FOR THE NORFOLK DISPOSAL SITE

CNIDARIA : ANTHOZOA
- Anthozoa spp.

PLATYHELMINTHES : TURBELLARIA
- Turbellaria spp.

NEMERTEA
- Nemertea spp.

ANNELIDA : POLYCHAETA
- *Aedicira* sp.
- *Aglaophamus circinata* (Verrill)
- *Aglaophamus verrilli* (McIntosh)
- *Amastigos caperatus* Ewing and Dauer
- *Ampharete acutifrons* Grube
- *Ampharete americana* Day
- *Ampharete arctica* Malmgren
- *Ampharete parvadentata* Day
- Ampharetidae spp.
- Amphinomidae sp.
- *Ancistrosyllis hartmanae* Pettibone
- *Antinoella sarsi* (Malmgren)
- *Apoprionospio pygmaea* (Hartman)
- Arabellidae sp.
- *Aricidea catherinae* Laubier
- *Aricidea fragilis* Webster
- *Aricidea wassi* Pettibone
- *Armandia maculata* (Webster)
- *Asabellides oculata* (Webster)
- *Asychis carolinae* Day
- *Asychis elongata* (Verrill)
- *Autolytus* spp.
- *Boccardia* sp.
- *Brania pusilla* (Dujardin)
- *Brania welfleetensis* Pettibone
- *Capitella capitata* (Fabricius)
- *Capitella* spp.
- Capitellidae spp.
- Cirratulidae spp.
- *Cirrophorus furcatus* (Hartman)
- *Clymenella* spp.
- *Clymenella torquata* (Leidy)
- *Diapatra cuprea* (Bosc)
- Dorvilleidae spp.
- *Drilonereis longa* Webster
- *Drilonereis magna* Webster and Benedict
- *Drilonereis* spp.
- *Eteone heteropoda* Hartman
- *Eteone lactea* Claparede
- *Eteone longa* (Fabricius)
- *Eumida sanguinea* (Oersted)
- *Exogene hebes* (Webster and Benedict)
- *Glycera americana* Leidy
- *Glycera capitata* Oersted

Glycera dibranchiata Ehlers
Glycera robustus Ehlers
Glycera spp.
Goniadella gracilis (Verrill)
Gyptis brevipalpa (Hartmann-Schroder)
Harmothoe extenuata (Grube)
Hemipodus roseus Quatrefages
Leitoscoloplos fragilis (Verrill)
Leitoscoloplos robustus (Verrill)
Lepidonotus sublevis Verrill
Lumbrineridae spp.
Lumbrinerides acuta (Verrill)
Lumbrineris fragilis (Muller)
Lumbrineris tenuis Verrill
Macroclymene zonalis (Verrill)
Magelona sp.
Maldanidae spp.
Marphysa belli (Audouin and Milne-Edwards)
Mediomastus ambiseta (Hartman)
Microphthalmus sczelkowii Mecsnikow
Micropthalmus similis Bobretsky
Microphthalmus fragilis Bobretzky
Minuspio cirrifera (Wiren)
Nephtyidae spp.
Nephtys bucera Ehlers
Nephtys incisa Malmgren
Nephtys picta Ehlers
Nereidae spp.
Nereis acuminata Ehlers
Ninoe nigripes Verrill
Notocirrus spiniferus (Moore)
Notomastus hemipodus Hartman
Notomastus latericeus Sars
Onuphidae spp.
Onuphis eremita Audouin and Milne-Edwards
Ophelia denticulata Verrill
Ophelia sp.
Owenia fusiformis delli Chiaje
Paleanotus heteroseta Hartman
Paradoneis lyra (Southern)
Paranaitis polynoides (Moore)
Paranaitis speciosa (Webster)
Paraonidae spp.
Paraonis fulgens (Levinsen)
Paraonis pygoenigmatica Jones
Parapionosyllis longicirrata (Webster and Benedict)
Paraprionospio pinnata (Ehlers)
Pectinaria gouldii (Verrill)
Periploma spp.
Pherusa ehlersi Day
Phloe minuta (Fabricius)
Phyllodoce arenae Webster
Phyllodoce castanea (Marenzeller)
Phyllodoce mucosa Oersted
Phyllodocidae spp.

Pionosyllis sp.
Pisione remota (Southern)
Pista cristata (Muller)
Pista palmata (Verrill)
Pista quadralobata (Augener)
Podarke obscura Verrill
Polycirrus eximius (Leidy)
Polydora caulleryi Mesnil
Polydora commensalis Andrews
Polydora ligni Webster
Polydora socialis (Shmarda)
Polydora spp.
Polydora websteri Hartman
Polygordius spp.
Potamilla spp.
Proceraea sp.
Protodorvillea kefersteini (McIntosh)
Pseudeurythoe ambigua (Fuavel)
Sabellaria vulgaris Verrill
Scalibregma inflatum Rathke
Schistomeringos caeca (Webster and Benedict)
Schistomeringos rudolphi (delle Chiaje)
Scolelepis bousfieldi Pettibone
Scolelepis sp.
Scolelepis squamata (Mueller)
Scoloplos rubra (Webster)
Scoloplos spp.
Shaerosyllis sp.
Sigalion arenicola Verrill
Sigambra bassi (Hartman)
Sigambra spp.
Sigambra tentaculata (Treadwell)
Sphaerodoropsis sp.
Sphaerosyllis hystrix Claparede
Spio setosa Verrill
Spiochaetopterus oculatus Webster
Spionidae spp.
Spiophanes bombyx (Claparede)
Sthenelais boa (Johnston)
Sthenelais limicola (Ehlers)
Sthenelais spp.
Streblospio benedicti Webster
Streptosyllis pettiboneae Perkins
Syllidae spp.
Syllides convoluta Webster and Benedict
Syllides fulva (Marion and Bobretsky)
Syllides japonica Imajima
Syllides papillosa Hartman-Schroder
Terebellidae spp.
Travisia parva Day
Websterinereis tridentata (Webster)

ANNELIDA : OLIGOCHAETA
Oligochaeta spp.

ANNELIDA : HIRUDINEA
Hirudinea sp.

SIPUNCULA

Phascolion strombi (Montagu)

MOLLUSCA : GASTROPODA

Acanthodoris pilosa (Abildgaard)
Acteocina canaliculata (Say)
Anachis lafresnayi (Fischer and Bernardi)
Corambella depressa Balch
Crepidula fornicata (Linne)
Crepidula plana Say
Cylichnella bidentata (Orbigny)
Epitonium humphreysi (Kiener)
Eupleura caudata (Say)
Gastropoda spp.
Haminoea solitaria (Say)
Hyalina sp.
Mangelia cerina Kurtz and Stimpson
Marginella roscida Redfield
Mitrella lunata (Say)
Nassarius trivittatus (Say)
Natica pusilla Say
Nudibranchia spp.
Odostomia sp. a
Odostomia sp. b
Onchidoris aspera (Alder and Hancock)
Pleurobranchaea tarda Verrill
Polinices duplicatus (Say)
Rictaxis punctostriatus (Adams)
Turbonilla interrupta (Totten)
Turbonilla spp.
Turridae spp.

MOLLUSCA : BIVALVIA

Abra spp.
Anadara transversa (Say)
Bivalvia spp.
Cerastoderma pinnulatum (Conrad)
Crassinella lunulata (Conrad)
Crassostrea virginica (Gmelin)
Crenella decussata (Montagu)
Ensis directus Conrad
Gemma gemma (Totten)
Lyonsia hyalina Conrad
Macoma tenta Say
Mercenaria mercenaria (Linne)
Mulinia lateralis (Say)
Mysella planulata (Stimpson)
Mytilus edulis Linne
Nucula proxima Say
Pandora bushiana Dall
Pandora gouldiana Dall
Pandora spp.
Pandora trilineata Say
Parvilucina multilineata (Tuomey and Holmes)
Siliqua costata Say
Solemya velum Say
Spisula solidissima (Dillwyn)

Tellina agilis Stimpson
Yoldia limatula (Say)
Yoldia sp.

MOLLUSCA : POLYPLACOPHORA
Chaetopleura apiculata (Say)

MOLLUSCA : SCAPHOPODA
Scaphopoda sp.

ARTHROPODA : ISOPODA
Ancinus depressus (Say)
Chiridotea spp.
Cirolana polita (Stimpson)
Cyathura spp.
Edotea triloba (Say)
Ptilanthura tenuis (Harger)

ARTHROPODA : AMPHIPODA
Acanthohaustorius millsi Bousfield
Ampelisca vadorum Mills
Ampelisca verrilli Mills
Batea catherinensis Muller
Bathyporeia parkeri Bousfield
Bathyporeia quoddyensis Shoemaker
Bathyporeia sp.
Byblis serrata Smith
Caprellidae spp.
Corophium spp.
Elasmopis levis Smith
Erichthonius brasiliensis (Dane)
Gammarus daiberi Bousfield
Gammaropsis sp. cf. sutherlandi Nelson
Haustorius canadensis Bousfield
Hyperiidae spp.
Lembos smithi Holmes
Lembos websteri Bate
Liljeborgia sp.
Listriella barnardi Wigley
Listriella clymenellae Mills
Listriella sp.
Microprotopus raneyi Wigley
Monoculodes edwardi Holmes
Parametopella cypris (Holmes)
Parametopella stelleri Gurjanova
Paraphoxus spinosus Holmes
Protohaustorius spp.
Pseudunciola obliquua (Shoemaker)
Rildardanus spp.
Stenothoe minuta Holmes
Synchelidium americanum Bousfield
Synopiidae. sp.
Trichophoxus epistomus (Shoemaker)
Trichophoxus floridanus (Shoemaker)
Unciola dissimilis Shoemaker
Unciola irrorata Say
Unciola serrata Shoemaker
Unciola spp.

ARTHROPODA : CUMACEA

Cyclaspis pustulata Zimmer
Cyclaspis varians Calman
Diastylis sp.
Eudorella spp.
Eudorella trunculata (Bate)
Oxyurostylis smithi Calman
Pseudoleptocuma minor (Calman)

ARTHROPODA : MYSIDACEA
Mysidopsis bigelowi Tattersall
Neomysis americana (Smith)

ARTHROPODA : TANAIDACEA
Leptognatha caeca (Harger)

ARTHROPODA : DECAPODA
Albunea paretii Guerin
Cancer irroratus Say
Crangon septemspinosa Say
Dissodactylus mellitae Rathbun
Euceramus praelongus Stimpson
Libinia emarginata Leach
Majidae spp.
Ovalipes ocellatus (Herbst)
Pagurus spp.
Pinnotheres ostreum Say
Thor floridanus Kingsley

ARTHROPODA : STOMATOPODA
Nannosquilla grayi (Chase)

PHORONIDA
Phoronis psammophila Cori

ECHINODERMATA : ASTEROIDEA
Asterias forbesii (Desor)
Asteroidea spp.

ECHINODERMATA : ECHINOIDEA
Arbacia punctulata (Lamarck)
Echinarachnius parma (Larmack)
Mellita quinquiesperforata (Leske)

ECHINODERMATA : HOLOTHUROIDEA
Caudina arenata (Gould)
Leptosynapta inhaerens (Ayres)

ECHINODERMATA : OPHIUROIDEA
Ophiuroidea spp.

CHAETOGNATHA
Chaetognatha spp.

HEMICHORDATA
Saccoglossus spp.

CHORDATA : CEPHALOCHORDATA
Branchiostoma virginiae Hubbs

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